

Analysis of Work Measurement Techniques for NASA/KSC's Shuttle Processing

Amanda M. Mitskevich, Susan L. Murray, Robert R. Safford, and William W. Swart
NASA Kennedy Space Center and University of Central Florida

ABSTRACT: Time standards are usually developed for highly repetitive tasks of short duration. Therefore, most of the work measurement techniques available for producing standards are formulated for this level of activity. There is an increasing need for standards on tasks that are less repetitive and of longer duration. It is also necessary to continue to ensure that the development of the standards is cost effective. One way to assist in minimizing cost is to select the appropriate technique for the application by considering development and implementation costs, feasibility, and consistency of the techniques. This paper presents a study of work measurement techniques as applied to space shuttle processing at the Kennedy Space Center with respect to these factors.

Work Measurement Techniques

Work Measurement is one of the original industrial engineering methodologies. Its origins date to Frederick Taylor's work improving the efficiency of the U.S. steel industry prior to the turn of the century. The primary purpose of work measurement is to determine the time standards for particular operations. A time standard can be defined as the amount of time required to perform a given task based upon a prescribed method assuming: experienced and trained operators, normal work pace; set working conditions; and specific tools, material, and equipment. It is comprised of several components including the setup times prior to the operation, the operational time, allowances for needs of the worker, allowances for the working conditions, and cleanup activities after the task is completed. These time standards can be used for a variety of industrial engineering and management programs including: performance measurement, wage incentives, line balancing, scheduling, methods analysis, budgetary forecasting, and other activities.

A variety of work measurement techniques have been developed to assist in establishing time standards. These techniques vary in developmental time requirements, training time requirements, quality of the resulting time standards, and degree of acceptance. A list of commonly used techniques includes: time study, predetermined time standard systems, historical data, estimation, micromotion analysis, standard data, and work sampling. The technique selection is based on the characteristics of the task, the intended use of the resulting time standards, and the cost of development and implementation for each technique.

Shuttle Processing at the Kennedy Space Center (KSC)

KSC is responsible for preparing Space Shuttles for approximately eight missions per year. This includes all activities that occur between wheel stop at landing of the previous mission and the shuttle clearing the launch tower for the next mission. The fleet that supports this flight manifest consists of four reusable orbiters, refurbished solid rocket boosters (SRB), expendable external tanks (ET) and payloads. The shuttles are processed in parallel for their individual missions.

The shuttle processing for each flight includes the testing and checkout of the orbiter, the two SRB's, and the ET. These components are processed separately through several facilities before integration as a "shuttle" in the Vehicle Assembly Building (VAB). The shuttle then is rolled-out to the launch pad for final checkout and launch. Shuttle processing usually averages 130 days, depending upon the maintenance activities required for that particular flow. Orbiter processing is normally completed in an average of 90 days. Because of its complexity,

expense, consumption of resources, and impact on the shuttle processing schedule, orbiter processing receives the most attention during a flow.

During orbiter processing at KSC, data is collected on how long a task has taken, not on how long it should take. This historical data, along with engineering estimates, are used for scheduling work and for high level measurements such as how many days it takes to complete processing an orbiter for flight. Some of these data collection and analysis systems were originally developed prior to the beginning of the space shuttle program, when NASA was launching expendable vehicles. Compared to the current space flight programs, there were fewer missions and no reusable components. The space shuttle program has moved NASA into an environment with increased task repetition. This, combined with a new era of concern about government spending, has prompted KSC to study the incorporation of industrial engineering techniques and tools that have traditionally been applied to manufacturing operations and some service and maintenance industries.

Need for Time Standards at KSC

The need for and use of time standards at KSC are quite similar to those of traditional industrial operations, but the application is unique. The orbiter processing environment is characterized by an increased concern with quality and safety. The tasks are performed on highly specialized hardware, requiring great care and precision. Due to this, the work force tends to be highly skilled, well trained, and motivated. However, since the current flight manifest provides an extremely low level of repetition in comparison with a traditional manufacturing environment, orbiter technicians do not climb the learning curve for specific tasks. Many of the tasks required for the maintenance and checkout of the orbiter are performed, at most, only once during the flow, and different technicians may perform the task each time. Therefore, typical benefits demonstrated by traditional learning curves are not readily apparent in this environment, and work measurement techniques that are based on learning curve applications must be adapted to compensate for this difference. Additionally, since the work is considered high tech, slow pace, long duration, and low repetition, several existing techniques are not appropriate and others must be modified to reflect this environment.

An additional constraint is that the design of the orbiter was driven by functionality, so access to much of the hardware for its servicing is extremely limited. The technicians often find themselves working in cramped areas and awkward postures, which slows the work pace and creates the need for allowances on specific jobs.

Incorporating work measurement techniques will allow time standards development at a lower operational level than is currently available at KSC. This increased level of detail will provide accurate and consistent information on how long a job should take, enabling orbiter processing to refine the scheduling of tasks by reducing the schedule's variability. With the current scheduling process, tasks tend to complete much earlier or later than the scheduled completion time, impacting the start times of subsequent jobs and creating variability in the schedule as a whole. The refined time standards will also allow NASA to measure operational performance at a significantly lower level. This will assist in identifying problems and sources of potential improvements at a degree currently not possible. Cost benefit analysis can be performed using this new data to better quantify changes and

improvements in support of ongoing process improvement efforts.

Selection of Orbiter System

The concentration for this work measurement study was on the checkout and test, the processing flow, of the orbiters in the Orbiter Processing Facilities (OPF). There are 24 major systems on each orbiter which require both planned and unplanned work during a flow to satisfy interval maintenance requirements. This work is described by work authorizing documents (WAD's) which can range from several pages to several hundred pages in length and can span from less than an hour to more than 8 hours. Planned work includes tasks that are driven by known interval maintenance requirements and functional testing; and unplanned work are tasks that become necessary due to unanticipated problems that occur during the processing. In general, individual planned tasks are performed anywhere from several times per flow to once every fifth flow. Planned work that is done at a minimum of once every flow is described as the "normal" flow and was the focus of this study, since it comprises the largest segment of work and is the most well-defined.

In order to determine effectiveness of applying work measurement for orbiter processing, a representative orbiter system was selected. This system is the Main Propulsion System (MPS). It was chosen primarily for its work content, criticality to orbiter processing, and span. The work content consists of many types of tasks including leak checks, hardware installations and removals, and visual inspections. This work is not only a functionally critical orbiter system, but is also on the critical path for scheduling other tasks. It therefore could have a significant impact on overall time span if improvements were made. Finally, the tasks for MPS span the entire range of time that an orbiter is in processing, providing a representation of the activities in a flow to encompass the fluctuation of resources.

Work Measurement Techniques Excluded Due to Infeasibility for the MPS

One of the decisions which was made at the beginning of the study was which work measurement techniques would be feasible for the orbiter processing environment. Several of the previously mentioned work measurement techniques were excluded from further consideration. They include standard data, micro-motion, and work sampling.

There is currently no standard data available at KSC, and standard data that is used in other industries is not tailored for use in the KSC environment. DoD 5010.15.1-M which contains standard data for use by the Department of Defense is one of the sources of standard data reviewed for applicability. Its level of detail was much greater than that deemed necessary or feasible at KSC.

Micro-motion study was also deemed to be inappropriate as it requires a very fine level of activity breakdown and repetition which are not attainable with the tasks in orbiter processing. The time it would take to set a standard at this level is not cost effective since each task in the study is performed only approximately eight times per year and can be over eight hours in length.

Finally, work sampling was also excluded from further study. The tasks performed on the orbiter are dissimilar and of a low frequency. Due to the low repetition, the sample size required to achieve accurate results would not be possible. There are other areas of shuttle processing

that have a greater level of repetition and a smaller task size where work sampling and standard data might be appropriate.

Adaptation of Traditional Work Measurement Techniques to Orbiter Processing

Other techniques were deemed appropriate for consideration in orbiter processing and were adapted for use in this environment. These include estimation, historical data, time study, and predetermined time standard systems (PDTS). The cost and variability of each method were measured to allow for the comparison of techniques. A comparison of their potential sources of variability is summarized in Figure 1.

Time values for estimation were generated using two methods. Data from the Computer Aided Planning and Scheduling System (CAPSS) was used as one source. CAPSS is a tool used to assist in preparing schedules for processing the shuttle components. The times included in CAPSS were developed by engineers and planners responsible for each particular orbiter system. The time values are updated periodically. Generally, these times include biases for the worst case scenarios and delays that may occur during the job. The cost for collecting and analyzing this information for the MPS was approximately 12 hours. This technique has the lowest cost, since the data already exists.

The other form of estimation that was applied was a survey of technicians with extensive experience in the maintenance performed on the MPS. Questions were developed pertaining to setup times, work time, and cleanup activities on each MPS normal flow task. The technicians were supplied with the paperwork that denotes the steps in the performance of the task. Consensus was used to arrive at the best answers. Some of the sources of variability include some bias for worst case scenario and varying levels of caution between estimators. However, some of this variability was reduced by using the consensus technique to arrive at the answers. It took the technicians approximately 40 hours to complete the survey. Compilation of the data took 16 hours.

Historical data was collected from the Shop Floor Data Collection System (SFDCS) which had been in use approximately one year at the time of this study. This system is used by the technician when any change in the status of work being performed occurs. This change is logged in through the use of a bar code scanner and can include logging into a task to begin work, logging out of a task if a delay is encountered while work is in progress, scanning back in after delay resolution, and logging out at task or shift completion. This system then is able to provide records of how long a task took to complete. Some of the problems with using this data include the newness of the system which affects the data's consistency, the inability to capture the "short" delays, and the lack of task level detail in the system. Retrieval of the data took approximately 40 hours; editing and compilation required 40 hours. Most of the time was spent on matching the higher task level detail recorded in the SFDCS to the lower level detail tracked by the task paperwork and necessary for comparison to the other work measurement methodologies.

The traditional time study was modified slightly for use at KSC. Because of the low repetition, segments of work were not predefined for the observers. They were provided with the task paperwork and allowed to develop the elements as the job was observed. Paperwork deviations, task delays, technician breaks and lunches, and other foreign elements

were recorded with the task setup, work, and cleanup time so that they could later be subtracted. Each job in the MPS study was observed at least once, with some duplicate observations being taken. No performance rating was applied because of the "normal" pace that was previously described. Additionally, the pace of the technicians was observed to be fairly consistent due to the safety and quality requirements in this environment. Personal, fatigue, and delay (PF&D) allowances were given at 15%, with some additional allowances included for particularly awkward or difficult tasks. The cost for collecting a sample with limited repetition on each MPS job was over 440 hours of labor. Recapping of those jobs to remove delays and to calculate times required 160 hours.

Due to the length of the tasks, the PDTs chosen was Maxi-MOST. It breaks down the task elements into larger blocks of motion than other PDTs, to better fit the NASA environment with its long task durations. The data collected with the direct observations and the task paperwork were used to determine the detailed motion patterns. Allowances were again applied as in the direct observations. Maxi-MOST requires a trained analyst and over 240 hours of analysis time on the MPS.

SOURCES OF VARIABILITY

Methodologies Sources	Direct Obs. (Time Study)	Maxi-MOST (PTDS)	SFDCS (Historical)	CAPSS/ Survey (Estimation)
Inconsistent Work Method	✓	✓	✓	✓
Error in Recording Data	✓	✓	✓	
Small Sample Size	✓		✓	
Operator Pace	✓		✓	
Changeable Work Content	✓		✓	
Changeable Work Conditions	✓		✓	
Lack of Task Familiarity		✓		✓
Extreme Case Bias				✓
Varying Caution Levels of Est.				✓

Figure 1

MPS Results

The task time values established by each work measurement technique were included in an MPS simulation model. The resulting MPS flow times were collected and the variabilities calculated for each work measurement technique, as shown in Figure 2. By comparing the variability with the cost, which is comprised of collection and analysis times, as shown in Figure 3, a tradeoff analysis can be performed for the selection of work measurement technique(s).

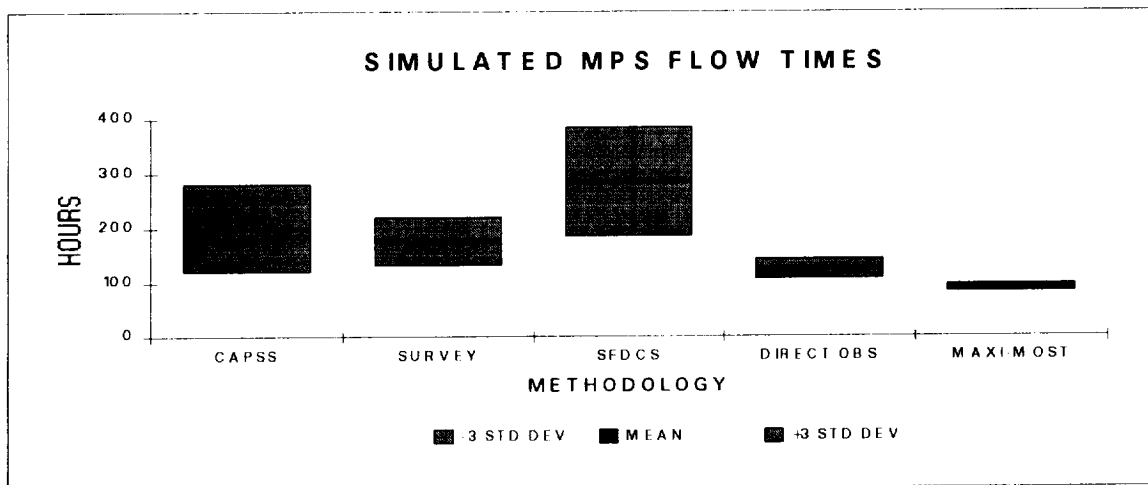


Figure 2

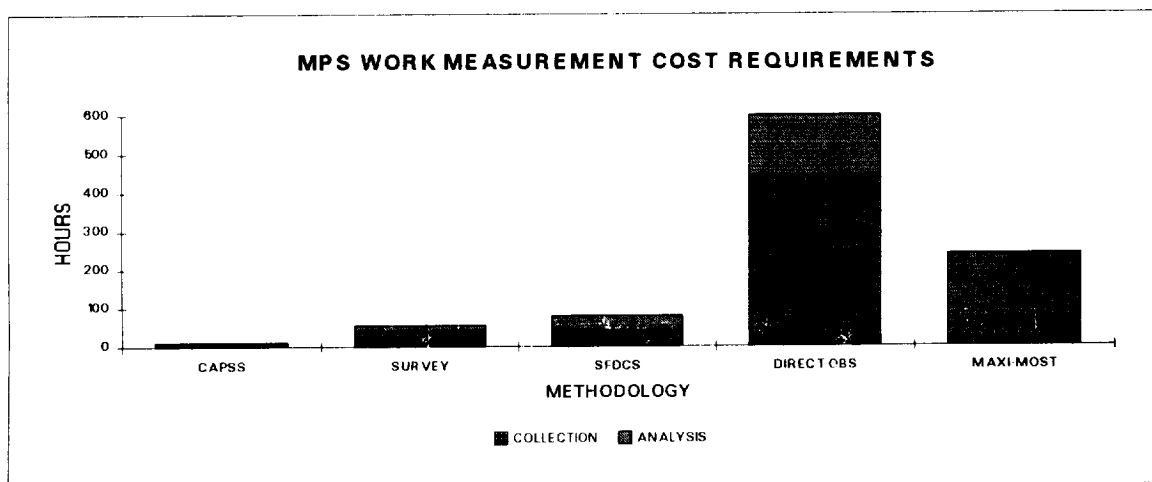


Figure 3

Conclusions

This research illustrated that traditional work measurement techniques can be adapted for use in unique operational environments such as orbiter processing at KSC. Additionally, by quantifying work measurement technique selection factors, a systematic method, rather than subjective approaches, can be incorporated in the given environment.

Cost and variability were chosen in this study as the most critical selection factors. The inclusion of cost as a factor was obvious. Low variability was desirable to improve the consistency of the resulting time standards and to enhance schedule performance. Currently the tradeoff analysis between these two conflicting objectives is subjective. Efforts are continuing to determine the cost of time standard variability to enable quantification of the selection process. Additional research is being conducted at NASA KSC to analyze the qualitative and quantitative benefits of time standards in this complex processing environment by expanding this initial study to include other orbiter systems. This information will assist in justifying the additional expense of improving the current method of establishing time values at KSC.